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A PANSOPHIC APPROACH FOR RELIABILITY GROWTH FOR ONE–SHOT DEVICES

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This report provides an approach using System Engineering Principles to the Reliability Growth for One–Shot Devices.

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I. OBJECTIVES

This report will provide an approach (combination of tools) to determine the inherent reliability of a One–Shot device. Most of the methods have been known to the Reliability, Availability, Maintainability (RAM) community and will not be elaborated on. The section, that has not been discussed, is the approach on the model that uses the principles of Linear Signal Processing, and feed back (Sections IV and V) to Reliability Growth, which are fundamental to System Engineering. If developed this model has the potential to eliminate the guess work from testing, and result in significant cost savings.

II. BACKGROUND

Reliability Growth for continuous systems (such as, communications) is not a new problem. MIL–HDBK–189 (U. S. Army Materiel System Analysis Activity (AMSAA's) Duane Model) addresses this approach. However there are some limitations to the Reliability Growth for One–Shot devices. One would be to consider growth during flight programs. This would be a good approach provided that the number of flights are considerably large (30 or more). With smaller sample size one cannot afford to have more than one or two failures during the flight program. For an especially visible program, even one or two flight failures would jeopardize the program. Recognizing that the whole purpose of a Reliability Growth Program should be based on finding as many failures as possible and eliminating the root cause (as depicted in Fig. 1). A test program with a small sample size seriously limits the ability to achieve a maximum reliability growth. Therefore, for any new program, the identification and correction of a small number of failures would not allow the system to approach its inherent reliability. Therefore, a flight program with a small sample size should be used only as a part of the verification for Reliability Growth.

III. SUBSYSTEM LEVEL TESTING

Subsystem level testing has been recommended by the Undersecretary of the Army for Operations and Research to enhance the reliability growth's shortcomings, due to limited number of samples. With today's modicum budget all efforts should be made to find new ways to enhance the Reliability Growth Program. Figure 2 describes a typical life cycle of a One–Shot device environment. In a real scenario transportation and war time buildup could become one phase. The actual environment especially the flight, has been transformed to continuous state by the following: To determine the flight environment, calculations should be made to find the stress levels that the missile will see during the flight. These calculations should be verified by instrumenting the missile during actual flights. The missile has to be tested, active and passive at levels above the worst case scenarios. For the first phase test duration must be a large factor multiplied by the actual flight duration. The remaining of the environments are accelerated testing and self explanatory. The combination of tests starting at the circuit card all the way to the missile should be in thousands of hours. Figure 3 provides an estimation of the number of hours at the missile level. Again these have arbitrarily been chosen and each program should develop the test hours and levels based upon its own requirements, cost, and schedule. Once the number of test hours have been established Figure 4 provides the breakdown, and the transformation to a continuous domain. For further enhancement this effort can be tied into AMSAA's study of "Physics of Failure".

IV. FEED BACK APPROACH

Once testing has started, one does not know exactly how effective the testing (test levels) are. My recommendations, which uses the feed back approach, done in System Engineering is to use data of previous system's (similar to the missile being developed), and determine if the testing has resulted in similar failures. Adjustment in test levels should be made accordingly. To enhance this process the principle of physics of Failure could also be applied. During a discussion with a colleague, it was pointed out that the previous data that was used for the feed back purposes can be used as "prior" for Bayesian statistics. Bayesian is another powerful tool for evaluating the Reliability Growth provided that the "prior" is used unbiasely.

V. USE OF LINEAR SIGNAL PROCESSING PRINCIPALS FOR RELIABILITY ENGINEERING

Sections IV and V are the areas that I believe have not been proposed for the Reliability Growth Programs. This approach uses energy application to the system. The overall system shall be modeled as a sequence of related subsystem models using linear system approaches. Where needed, subsystem nonlinearities will be addressed using piecewise linear or other techniques as described in Reference 1. Test conditions (e.g., vibration amplitudes and frequencies, temperature levels, humidity, etc.) will be utilized as inputs to the model. The output of the model will be an evaluation of the ability to achieve the overall system inherent reliability. The development of the overall system architecture shall address the integration of subsystem failure probabilities to define the system–level inherent reliability. In Linear Signal Processing it is assumed that a system such as h(t) has been impacted by a Delta function ($\delta(t)$) and the the result would be the H(t), which is the frequency, spectrum, or system response. My recommendation is to replace the delta function by (E(t)), which stands for Energy, (Fig. 5). This energy includes vibration, temperature, etc. Once this energy is applied to the system (missile) the result would be higher order differential equations, which could be solved by Laplace transform. Once the poles have been determined, the system's state can be evaluated depending on the location of the poles in relation to the $J\omega$ axis. That is if failures are present the system may act as under damped, critically damped, etc. This analysis could be done both for mechanical and electrical/ electronic frequency responses. The overall approach can be thought of as filter analysis. The missile acts as a filter and would respond a certain way to the energy applied. This approach can be applied both at the system level and subsystem level. The reliability response of a system is known, (Fig. 6). By developing this model, different inputs (energies) would be applied, and the response can be compared to the actual reliability response. Adjustments to the test levels can be made to obtain the actual reliability response. If developed, this model has the potential to eliminate guess work from testing, and result in significant cost savings.

VI. AMSAA ALSO USES FAILURE MODE PROJECTION MODEL FOR DISCRETE SYSTEMS THAT CAN BE USED FOR RELIABILITY GROWTH PROGRAMS

We have been discussing the use of simulation for Reliability Growth. My personal feelings are that there is no replacement for actual "shake and bake" of the hardware. Developing the software to do the simulation would be costly.

Simulation could be used not as a replacement for actual test, but as another method to verify the adequacy of the subsystem level testing.

VII. CONCLUSION

This report provides a method by which the testing of One–Shot Devices or (continuous systems) can be enhanced by the application of Linear Signal Processing techniques in order to augment the traditional testing methods. In today's fiscal environment of reduced funding for development and procurement of systems, this method will reduce the development cycle by determining the adequacy of test levels, identifying failures/failure modes. A comprehensive reliability growth program should be developed in such a way that other activities such as Qualification Test, or Environmental Stress Screening (levels), could become a by–product. Other proven Product Assurance tools, such as; a tight Failure, Reporting, Analysis, and Corrective Action System (FRACAS), Sneak Circuit Analysis, Electrical/Electronic Circuit Tolerance Analysis, Software Metrics, etc., should be planned, and executed as a building block for a successful Reliability Growth Program.

Note: Care must be taken in applying approaches, values, margins, etc. Each program must be planned based on its own requirements, cost, and schedule.

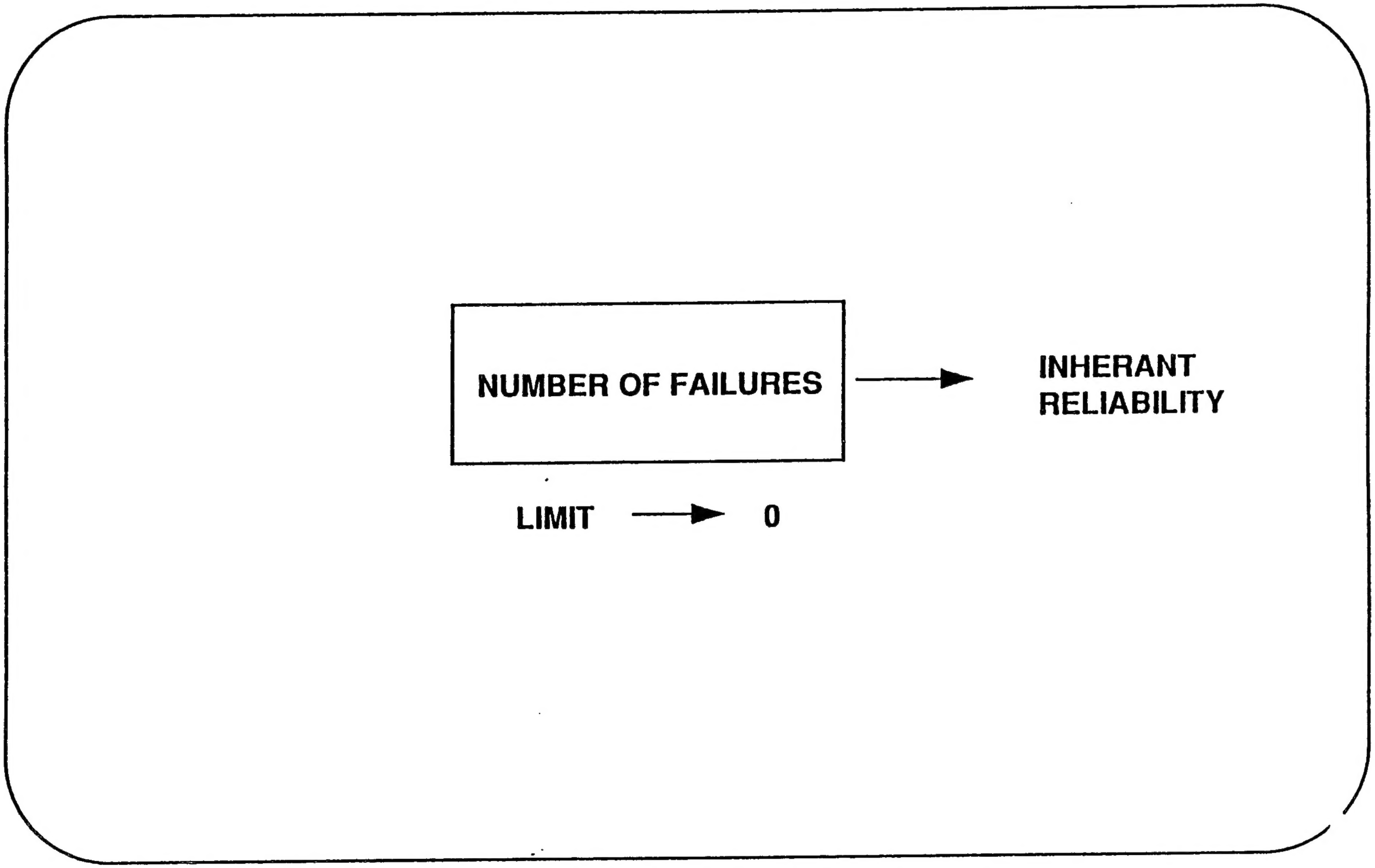
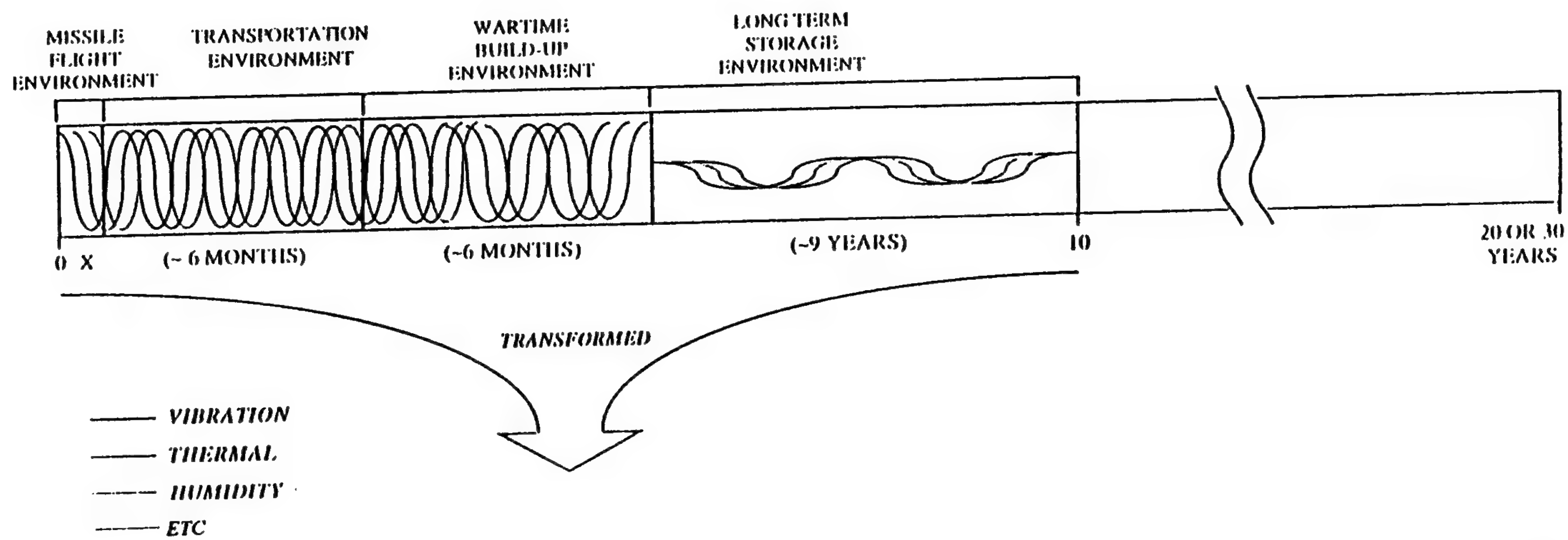


Figure 1. Process for Achieving the Inherent Reliability



THIS ANALYSIS IS DONE FOR 10 YEARS, WHERE RECERTIFICATION COULD BE PLANNED FOR. TO INCLUDE TOTAL LIFE OF THE MISSILE TEST LEVELS MAY BE MULTIPLIED BY A FACTOR OF 1.5 TO 2 TIMES THE LEVELS ESTABLISHED FOR THE TEN YEAR PERIOD, SO THAT THE DESIGN MARGINS ARE DEMONSTRATED FOR 20 OR 30 YEARS.

Figure 2. Typical Life Cycle of a One–Shot Device Environment

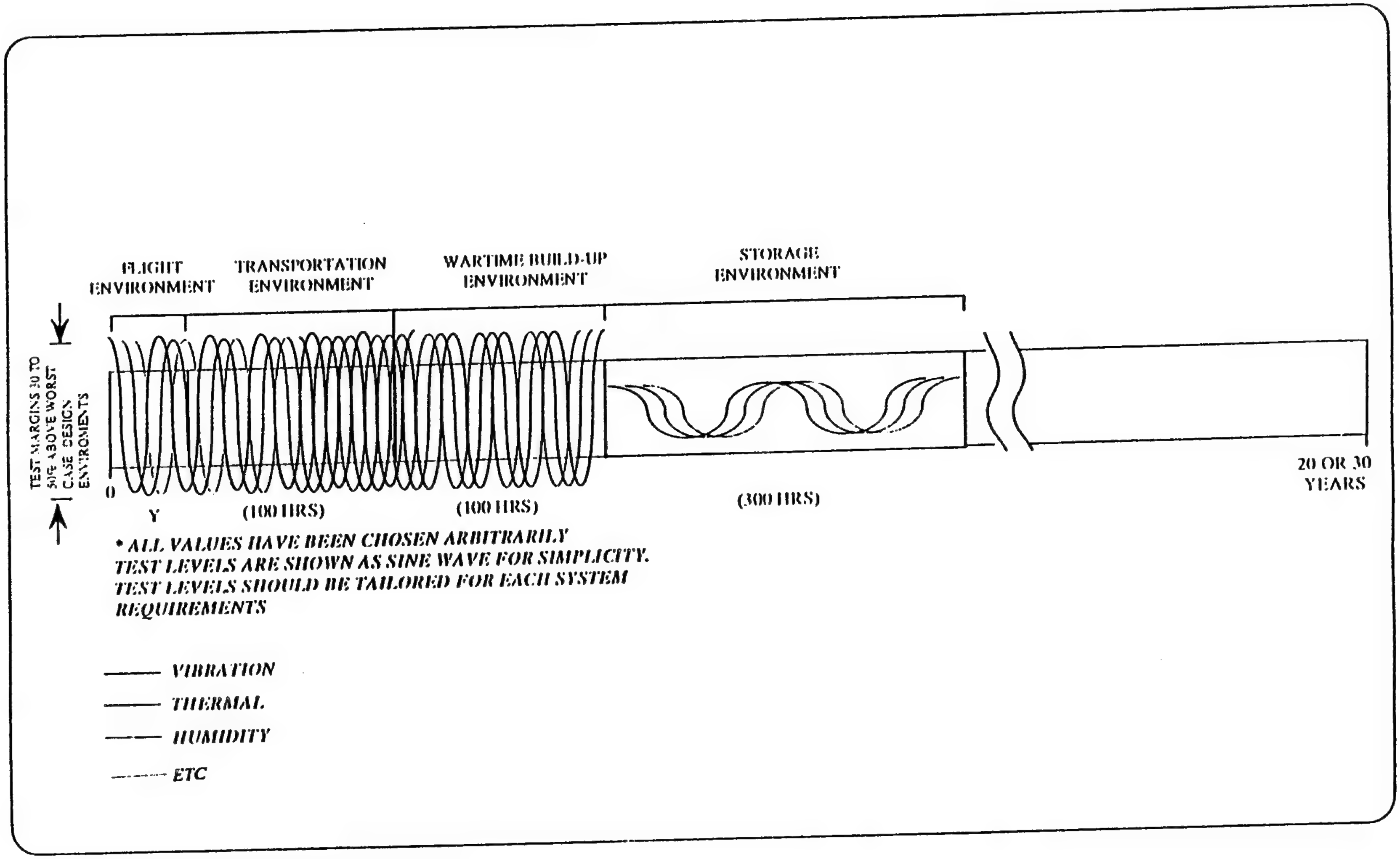


Figure 3. Estimation of the Number of Hours at the Missile Level

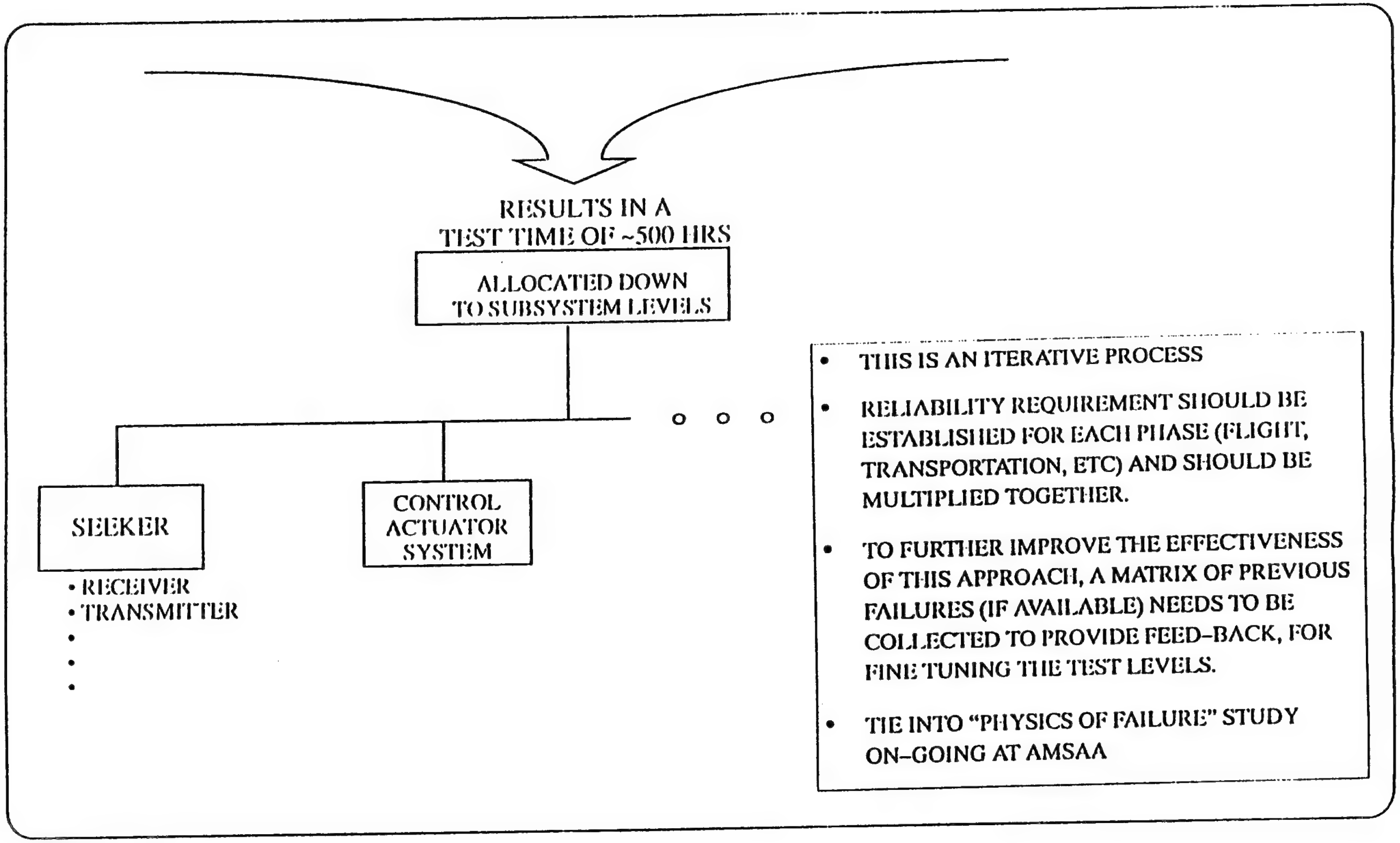


Figure 4. The Breakdown and the Transformation to a Continuous Domain

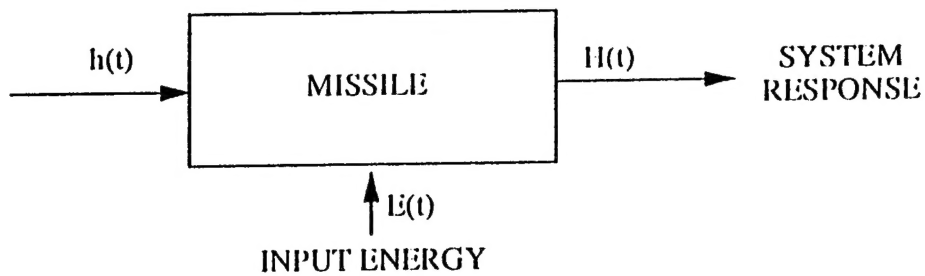


Figure 5. Use of Linear Signal Processing Principles for Reliability Growth

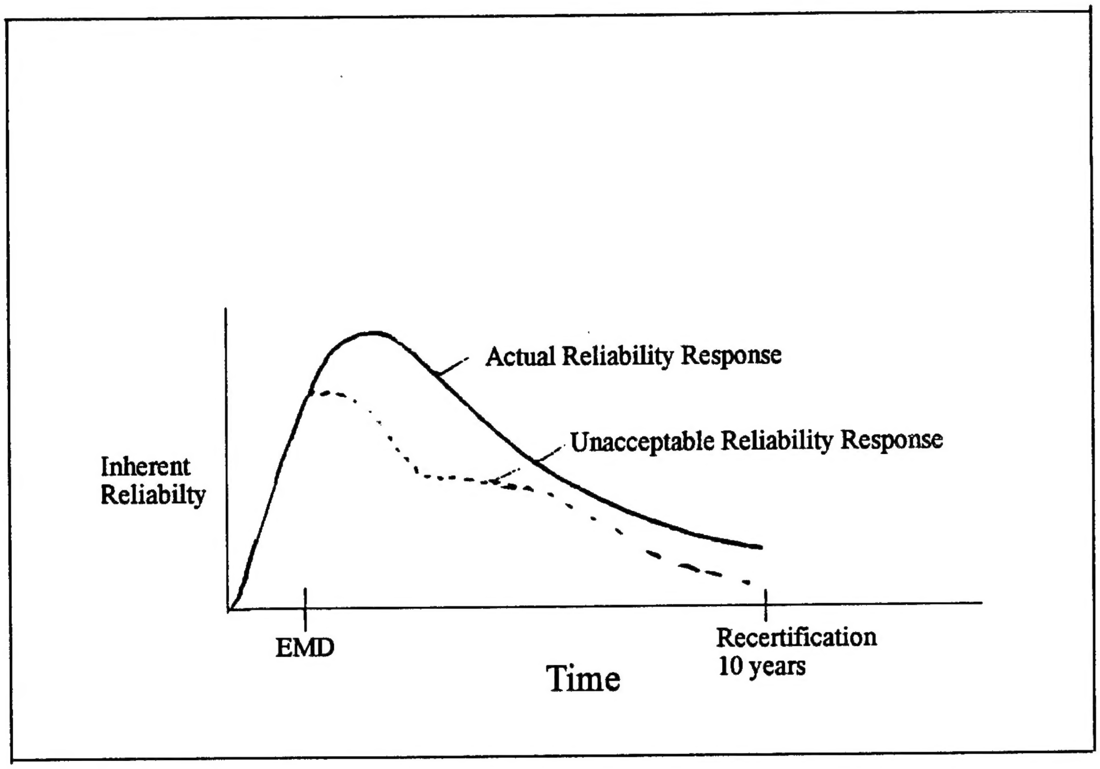


Figure 6. Reliability Response of a System

REFERENCE

1. Gilbert, S. M., Hays, R. D., Budge, M. C. Jr., and Bennett, L. D., "The Simulation of IF Soft and Hard Limiters at Baseband Frequencies". Undated.

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